Campus Infrastructure COVID-19 Mitigation Efforts

Chris Kopach
Assistant Vice President, Facilities Management and Incident Command System Commander

Paloma Beamer, Ph.D.
Professor, Public Health and a member of Public Health Advisory Coronavirus Team (PHACT)

October 28, 2021
We respectfully acknowledge the University of Arizona is on the land and territories of Indigenous peoples. Today, Arizona is home to 22 federally-recognized tribes, with Tucson being home to the O’odham and the Yaqui. Committed to diversity and inclusion, the University strives to build sustainable relationships with sovereign Native Nations and Indigenous communities through education offerings, partnerships, and community service.
Webinar Notes

• Please submit your questions in the Q&A tab at the bottom of your screen.

• The Chat function allows you to send chat messages to your colleagues in the meeting.

• The webinar Recording, the Q&A feed, the Chat feed, and any presentation materials will be available after the webinar at https://provost.arizona.edu/content/campus-webinars
Facilities Management Mitigation Efforts
What Has UArizona Done to Prepare Campus for Re-Entry?

- Ramped up cleaning and disinfecting beginning in January 2020.
- Use of Oxivir cleaner, which kills the COVID-19 virus.
- Adherence to CDC guidelines to ensure the health and safety of the campus community.
- Trained members of our Custodial Staff on COVID isolation, cleaning, including PPE and proper cleaning techniques.
- Centralized PPE purchasing and storage for the campus.
- Our Small Engine Shop has been converted to a disinfecting station, filling and replacing thousands of bottles of disinfectant to share across campus.
- Established Isolation Dorms and student isolation transportation.
- Campus Health provides voluntary vaccinations and COVID-19 testing for symptomatic cases.
- Student Union houses COVID-19 testing.
Preparing Campus for near-normal operations

To Date:
• 2,000 Sneeze Guards installed
• Signage installed in 100 buildings
• 1,530 Wall Mounted Hand Sanitizers installed
• 2,350 Touch-Free Paper Towel Dispensers installed
• 1,310 Toilet Seat Covers installed
• 8,000 MERV Filters installed
COVID Clean Ups – August/September 2021

<table>
<thead>
<tr>
<th>Date</th>
<th># of Trans.</th>
<th># of COVID Cleans</th>
<th># of Dorm Cleans</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/1/2021</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>8/2/2021</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>8/3/2021</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>8/4/2021</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8/5/2021</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>8/6/2021</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8/7/2021</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8/8/2021</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8/9/2021</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>8/10/2021</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>8/11/2021</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8/12/2021</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>8/13/2021</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>8/14/2021</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8/15/2021</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8/16/2021</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>8/17/2021</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8/18/2021</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8/19/2021</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>8/20/2021</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8/21/2021</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8/22/2021</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8/23/2021</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8/24/2021</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>8/25/2021</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>8/26/2021</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>8/27/2021</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>8/28/2021</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8/29/2021</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8/30/2021</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>8/31/2021</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date</th>
<th># of Trans.</th>
<th># of COVID Cleans</th>
<th># of Dorm Cleans</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/1/2021</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9/2/2021</td>
<td>5</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>9/3/2021</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9/4/2021</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9/5/2021</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9/6/2021</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9/7/2021</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>9/8/2021</td>
<td>1</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>9/9/2021</td>
<td>2</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>9/10/2021</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>9/11/2021</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9/12/2021</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>9/13/2021</td>
<td>3</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>9/14/2021</td>
<td>6</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>9/15/2021</td>
<td>4</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>9/16/2021</td>
<td>3</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>9/17/2021</td>
<td>5</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>9/18/2021</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9/19/2021</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9/20/2021</td>
<td>9</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>9/21/2021</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>9/22/2021</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>9/23/2021</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>9/24/2021</td>
<td>5</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>9/25/2021</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9/26/2021</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9/27/2021</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9/28/2021</td>
<td>1</td>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>

Total # of COVID Cleans for August and September 2021 = 71
The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Founded in 1894, is a global professional society with over 57,000 members that are committed to serve humanity by advancing the arts and sciences of heating ventilation, air conditioning, refrigeration and their allied fields.

As an industry leader in research, standards, writing, publishing, certification and continuing education, ASHRAE and its members are dedicated to promoting a healthy and sustainable built environment for all, through strategic partnerships with organizations in the HVAC&R community and across related industries.
## Classroom Air Change Review

<table>
<thead>
<tr>
<th>Building</th>
<th>Descr</th>
<th>Room</th>
<th>Year of Original Construction</th>
<th>Room SF</th>
<th>Room Height (ft)</th>
<th>Room Volume (cf)</th>
<th>Total CFM/CFM/sf</th>
<th>Outside Air CFM</th>
<th>AHU Name, DWG Year</th>
<th>AHU Total Supply Air CFM</th>
<th>AHU Outside Air CFM</th>
<th>AHU Outside Air %</th>
<th>Total Supply Air Changes/Air Change/HR</th>
<th>Outside Air Changes/Air Change/HR x (Air Changes/Hr)</th>
<th>Air Changes/Hr (Plant, includes MERV 13 filter, efficiency factor for recirculated air)</th>
<th>Pro-Rated Occupancy Limit (Baseline 6 Air Changes/HR Min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>Student Union Memorial Center</td>
<td>252</td>
<td>2001</td>
<td>700</td>
<td>13</td>
<td>9,100</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Student Union Memorial Center</td>
<td>256</td>
<td>2001</td>
<td>884</td>
<td>13</td>
<td>10,842</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Student Union Memorial Center</td>
<td>264</td>
<td>2001</td>
<td>845</td>
<td>13</td>
<td>10,985</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>Architecture</td>
<td>A304</td>
<td>1965</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>89.01</td>
<td>Mathematics Teaching Lab</td>
<td>120</td>
<td>1998</td>
<td>131</td>
<td>9</td>
<td>1,179</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>89.01</td>
<td>Mathematics Teaching Lab</td>
<td>124</td>
<td>1998</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>77</td>
<td>Gould-Simpson</td>
<td>228A</td>
<td>1985</td>
<td>1,051</td>
<td>9</td>
<td>9,459</td>
<td>14,840</td>
<td>14.1</td>
<td>0.56</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
What is MERV?

Minimum Efficiency Reporting Value, commonly known as MERV, is a measurement scale designed in 1987 by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) to report the effectiveness of air filters in more detail than other ratings.

Basically, the higher the MERV rating, the higher the air filtration capabilities of a particular filter.

MERV ratings range from 1 to 20, with 1 being the lowest level of filtration, and 20 being the highest.

Filters that are MERV 16 through 20 are usually only found in hospitals, cleanrooms, and nuclear power plants. The home air filters you're looking for are rated anywhere between MERV 5 and 13.
<table>
<thead>
<tr>
<th></th>
<th>MERV 8</th>
<th></th>
<th>MERV 11</th>
<th></th>
<th>MERV 13</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pollen</td>
<td>✓</td>
<td>Pollen</td>
<td>✓</td>
<td>Pollen</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Dust/Lint</td>
<td>✓</td>
<td>Dust/Lint</td>
<td>✓</td>
<td>Dust/Lint</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Dust Mites</td>
<td>✓</td>
<td>Dust Mites</td>
<td>✓</td>
<td>Dust Mites</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Debris</td>
<td>✓</td>
<td>Debris</td>
<td>✓</td>
<td>Debris</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Pet Dander</td>
<td>✓</td>
<td>Pet Dander</td>
<td>✓</td>
<td>Pet Dander</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Mold Spores</td>
<td>✓</td>
<td>Mold Spores</td>
<td>✓</td>
<td>Mold Spores</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Car Fumes &amp; Smog</td>
<td>✓</td>
<td>Car Fumes &amp; Smog</td>
<td>✓</td>
<td>Car Fumes &amp; Smog</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Tobacco Smoke</td>
<td>✓</td>
<td>Tobacco Smoke</td>
<td>✓</td>
<td>Tobacco Smoke</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Smoke</td>
<td>✓</td>
<td>Smoke</td>
<td>✓</td>
<td>Smoke</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Bacteria</td>
<td>✓</td>
<td>Bacteria</td>
<td>✓</td>
<td>Bacteria</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Virus Carriers</td>
<td>✓</td>
<td>Virus Carriers</td>
<td>✓</td>
<td>Virus Carriers</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Microscopic Allergens</td>
<td>✓</td>
<td>Microscopic Allergens</td>
<td>✓</td>
<td>Microscopic Allergens</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>
ASHRAE EPIDEMIC TASK FORCE
Core Recommendations for Reducing Airborne Infectious Aerosol Exposure in Buildings

1. Follow public health guidelines
2. Increase ventilation, filtration, and air cleaning
3. Air distribution: promote mixing of space air without causing strong air currents
4. HVAC Operations: maintain temperatures, humidity, and clean air supply
5. Verify that HVAC systems are functioning as designed

Steps taken by FM to Reduce Covid Exposure via HVAC Systems

- Monitored and implemented guidance coming from the CDC, WHO, ASHRAE, etc.
- Evaluated all campus air handlers to ensure proper operations
- Evaluated and documented the air changes per hour in all classrooms
- Increased ventilation to maximize fresh air entering our buildings
- Increased air filtration levels to MERV 13 in all major air handlers
- Continue to service all campus air handlers on a quarterly schedule
- Purchased desktop carbon dioxide (CO2) monitors* and HEPA filtered air scrubbers which are available for use in areas with lower air changes per hour

*CO2 monitors indicates the level of exhaled air in a room – and may serve as a proxy indicator for the risk of Covid-19 virus particles spread through aerosols, if infected individuals are present.
Occupational Exposure and Ventilation Principles

Paloma I. Beamer, PhD
Past President, International Society of Exposure Science

Professor, Environmental Health Sciences, College of Public Health
Asthma and Airway Disease Research Center
Bio5 Institute
Chemical and Environmental Engineering
American Indian Studies (GIDP)
Risk Minimization and Prevention of Infection

• Probability of infection risk is a function of the total dose of the virus during an incubation period

• Focus on controlling...

- Frequency
- Intensity
- Duration
Fundamental Control Assumptions

- All exposures can be controlled to some degree and by some method.
- Controls may not completely control the exposure.
- More than one control may be useful or required.
- **Using multiple controls simultaneously will increase the overall effectiveness in minimizing risk and preventing infection.**
Exposure Control must consider....

- source (infected person)
- pathway
- susceptible person

https://tinyurl.com/FAQ-aerosols
Figure: time for particles of different sizes to settle to the ground in still air, from the height of a person. From the CDC “Aerosols 101” presentation

Particle Settling in Still Air

Time to settle 5 feet by unit density spheres

- 0.5 μm: 41 hours
- 1 μm: 12 hours
- 3 μm: 1.5 hours
- 10 μm: 8.2 minutes
- 100 μm: 5.8 seconds

Aerodynamic diameter definition: diameter of a unit density sphere that settles at the same velocity as the particle in question

https://tinyurl.com/FAQ-aerosols
Hierarchy of Controls

1. **Elimination**
   - Physically remove the hazard

2. **Substitution**
   - Replace the hazard

3. **Engineering Controls**
   - Isolate people from the hazard

4. **Administrative Controls**
   - Change the way people work

5. **PPE**
   - Protect the worker with Personal Protective Equipment

The hierarchy indicates the order of effectiveness, with elimination being the most effective and PPE being the least effective.
Multi-pronged virus prevention techniques

- **Elimination**
  - Remote Work
  - Reduced Occupancy

- **Community Protection**
  - Facemasks
  - Covid Watch
  - Symptom Check

- **Engineering Controls**
  - Increased air flow
  - Barriers
  - Improved HVAC filters
  - Room Redesign
  - Portable air cleaners

- **Administrative**
  - Housekeeping
  - Disinfection
  - Directional Flow
  - Training
  - Communication

- **Personal Protection**
  - Respirators
  - Hand Hygiene
  - Physical Distance

- **Community Protection**
  - Facemasks
  - Covid Watch
  - Symptom Check

- **Engineering Controls**
  - Increased air flow
  - Barriers
  - Improved HVAC filters
  - Room Redesign
  - Portable air cleaners

- **Administrative**
  - Housekeeping
  - Disinfection
  - Directional Flow
  - Training
  - Communication

- **Personal Protection**
  - Respirators
  - Hand Hygiene
  - Physical Distance

Increasing effectiveness
Ventilation and Airborne Transmission

Goal: Reduce the build-up of aerosols that potentially contain SARS-CoV-2 to reduce inhalation exposure and dose

Clean the air by filtering
- Upgrade filters in HVAC system
- Use portable air cleaners

Dilute the concentration
- Open windows and doors when possible
- Increase outdoor air delivery rate in HVAC system

Maintenance and evaluation
- Measure ventilation rates to ensure working as planned
- Change filters regularly
- Supplement with portable air cleaners as necessary
HVAC systems and filters

• Minimum Efficiency Reporting Value (MERV) from an ASHRAE 52.2 test
  • MERV ranges from 1 to 16; higher MERV = higher efficiency
  • MERV ≥13 (or ISO ePM1) are efficient at capturing airborne viruses

• High efficiency particulate air (HEPA) filters are more efficient than MERV 16 filters, but can’t be used in most commercial HVAC systems

• Ensure ducts are cleaned and sealed with no leaks

https://www.ashrae.org/technical-resources/filtration-disinfection#mechanical
Filtration Mechanisms
Relationship between Flow, ACH, Occupancy

• Flow rate (Q) is the volume of air that enters a space per unit time
  • Cubic feet per minute (CFM)
  • Liters per second (L/s)

• Air Exchange Rate (ACH) is the amount of time it takes to completely replace the complete volume of air of the room and is often reported in ACH (air changes per hour)
  • \( \text{ACH} = \frac{Q}{V} \)
  • \( V = \text{room volume} \)

• Indoor air quality guidelines are often normalized by number of occupants (N)
  • \( Q \text{ per person} = \frac{Q}{N} = \text{ACH} \times \frac{V}{N} \)
Ventilation Recommendations

• WHO Roadmap to Ventilation during COVID-19
  • Non-residential Settings
    • 10 L/s/person
    • https://apps.who.int/iris/bitstream/handle/10665/339857/9789240021280-eng.pdf?sequence=1&isAllowed=y

• Harvard Healthy Buildings
  • 4-6 ACH for non-clinical settings
  • https://jamanetwork.com/journals/jama/fullarticle/2779062
How to use a CO2 monitor to measure ACH?

• Measure CO₂ steady state concentration, number of people and room volume
• Use calculator to estimate air exchange rate
  • Harvard Healthy Buildings Programs
  • [https://docs.google.com/spreadsheets/d/1wG0dO0Su75iBuUCmY5WpfYtQITKbQ1UzJOeBVbDxJks/edit#gid=1039758887](https://docs.google.com/spreadsheets/d/1wG0dO0Su75iBuUCmY5WpfYtQITKbQ1UzJOeBVbDxJks/edit#gid=1039758887)

5. Estimate the target volumetric flow of outdoor air. Multiply the volume of the classroom (in cubic feet) times the target air changes per hour and divide by 60 minutes per hour.
   - e.g., For a target of 4 ACH in a 5000 ft³ classroom, 5000 * 4 / 60 = 333 cfm

6. Estimate the steady state CO₂ concentration using the following formula:

\[ C_{\text{steady-state}} = \frac{\text{CO₂ generation rate} + \text{target volumetric flow} \times \text{outdoor CO₂} \times 1 \times 10^{-6}}{\text{target volumetric flow} \times 1 \times 10^{-3}} \]

Continuing the example above, \( C_{\text{steady-state}} = \frac{6.1340 \text{ cfm} + 333 \text{ cfm} \times 600 \text{ ppm} \times 1 \times 10^{-6}}{333 \text{ cfm} \times 1 \times 10^{-3}} = 604 \text{ ppm CO₂} \)

This method only considers the dilution effect due to outdoor air flow. If part of your air supply is filtered through a MERV 13 or higher efficiency filter, or a portable air cleaner with a HEPA filter, you may use a lower target air exchange rate for this calculation as long as the total air changes per hour of clean air still meets the recommended ACH target. For example, if your mechanical ventilation can provide 5 ACH, estimate the steady state concentration at 3 ACH considering you could add 2 ACH with portable air cleaners to meet the 5 ACH target.

* Now that you’ve done this calculation, you can use your CO₂ monitor while class is in session to evaluate whether ventilation is adequate. In the example presented here, if the CO₂ sensor read around 600 ppm while the 14 students and 1 teacher were in class, we’d know we were meeting the stated target of 4 ACH of outdoor air ventilation. If we noticed the CO₂ sensor consistently read 1400 ppm while the 14 students and 1 teacher were in class, we’d want to check the ventilation because the increased steady-state CO₂ concentration indicates that the actual ACH is below the stated target of 4 ACH. In this way, CO₂ sensors can be used to determine when ventilation may not be adequate.*
Using a Simple-to-Read Carbon Dioxide (CO₂) Monitor to Evaluate Ventilation in Your Workspace

Proper ventilation can help decrease COVID-19 transmission indoors.

1. What is a CO₂ Monitor?
   - CO₂ monitors help you determine how much of the air in a room has been exhaled by you or someone else. High CO₂ levels mean more exhaled air.
   - The more exhaled air there is building up in a room, the more likely it is that if someone in the room has COVID-19 (even without symptoms), the virus is circulating in the room’s air.

2. How do I use a CO₂ Monitor?
   - Place monitor near the middle of a room, away from the incoming AC vents, and about 5 feet off the floor.
   - Some monitors use color-coded lights to indicate different levels.

<table>
<thead>
<tr>
<th>CO₂ Level</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>400 - 700</td>
<td>Ventilation is good. Risk is minimal.</td>
</tr>
<tr>
<td>700 - 1000</td>
<td>CO₂ levels are elevated. Keep an eye on monitor, and open windows and doors if possible.</td>
</tr>
<tr>
<td>More than 1000</td>
<td>More than 1% of the air in the space has been exhaled by someone. Consider taking a quick break and having everyone leave the space until levels drop below 700.</td>
</tr>
</tbody>
</table>

3. What kind of CO₂ monitor should I get, and where can I get it?
   - NDIR (non-dispersive infrared) CO₂ monitors work the best and cost about $100-$200.
   - Some options for purchasing monitors online:
     - Indoor CO2 Meter
     - PCE-CMM 5
     - CO2 Detector

Note: While UV-C lamps, HEPA filters, portable air cleaners, and some HVAC filters* can lower the amount of virus in the air, they won't change CO₂ levels.

*MERV-13 filters or higher are recommended to minimize virus transmission, but not all HVAC systems are compatible. Check your system requirements before installing new filters.
Using a Simple-to-Read Carbon Dioxide (CO₂) Monitor to Evaluate Ventilation in Your Workspace

Proper ventilation can help decrease COVID-19 transmission indoors.

1. What is a CO₂ Monitor?
- CO₂ monitors help you determine how much of the air in a room has been exhaled by you or someone else. High CO₂ levels mean more exhaled air.
- The more exhaled air there is building up in a room, the more likely it is that if someone in the room has COVID-19 (even without symptoms), the virus is circulating in the room’s air.

2. How do I use a CO₂ Monitor?
- Place monitor near the middle of a room, away from the incoming AC vents, and about 5 feet off the floor.
- Some monitors use color-coded lights to indicate different levels.

<table>
<thead>
<tr>
<th>CO₂ Level</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>400 - 700</td>
<td>Ventilation is good. Risk is minimal.</td>
</tr>
<tr>
<td>700 - 1000</td>
<td>CO₂ levels are elevated. Keep an eye on monitor, and open windows and doors if possible.</td>
</tr>
<tr>
<td>More than 1000</td>
<td>More than 1% of the air in the space has been exhaled by someone. Consider taking a quick break and having everyone leave the space until levels drop below 700.</td>
</tr>
</tbody>
</table>

Note: While UV-C lamps, HEPA filters, portable air cleaners, and some HVAC filters* can lower the amount of virus in the air, they won't change CO₂ levels.

*MERV-13 filters or higher are recommended to minimize virus transmission, but not all HVAC systems are compatible. Check your system requirements before installing new filters.

3. What kind of CO₂ monitor should I get, and where can I get it?
- NDIR (non-dispersive infrared) CO₂ monitors work the best and cost about $100-$200.
- Some options for purchasing monitors online:
  - Indoor CO₂ Meter
  - PCE-CMM 5
  - CO₂ Detector
Using a Simple-to-Read Carbon Dioxide (CO₂) Monitor to Evaluate Ventilation in Your Workspace

Proper ventilation can help decrease COVID-19 transmission indoors.

1. What is a CO₂ Monitor?

- CO₂ monitors help you determine how much of the air in a room has been exhaled by you or someone else. High CO₂ levels mean more exhaled air.
- The more exhaled air there is building up in a room, the more likely it is that if someone in the room has COVID-19 (even without symptoms), the virus is circulating in the room’s air.

2. How do I use a CO₂ Monitor?

- Place monitor near the middle of a room, away from the incoming AC vents, and about 5 feet off the floor.
- Some monitors use color-coded lights to indicate different levels.

<table>
<thead>
<tr>
<th>CO₂ Level</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>400 - 700</td>
<td>Ventilation is good. Risk is minimal.</td>
</tr>
<tr>
<td>700 - 1000</td>
<td>CO₂ levels are elevated. Keep an eye on monitor, and open windows and doors if possible.</td>
</tr>
<tr>
<td>More than 1000</td>
<td>More than 1% of the air in the space has been exhaled by someone. Consider taking a quick break and having everyone leave the space until levels drop below 700.</td>
</tr>
</tbody>
</table>

3. What kind of CO₂ monitor should I get, and where can I get it?

- NDIR (non-dispersive infrared) CO₂ monitors work the best and cost about $100-$200.
- Some options for purchasing monitors online:

*Note: While UV-C lamps, HEPA filters, portable air cleaners, and some HVAC filters* can lower the amount of virus in the air, they won't change CO₂ levels.

*MERV-13 filters* or higher are recommended to minimize virus transmission, but not all HVAC systems are compatible. Check your system requirements before installing new filters.

---

*Image of a CO₂ monitor*
Selecting a Portable Air Cleaner

- If air exchange is less than 6 ACH:
  - Calculate flow in CFM that you need to reach 6 ACH
  - Air cleaner should have Clean Air Delivery Rate (CADR) that equals that flow

**PM$_{2.5}$ CADR (m$^3$/h)**

**PM$_{2.5}$ CADR (CFM)**

**CADR:** Clean Air Delivery Rate, the most important metric in choosing an air purifier
**PM2.5:** Mass of all particles 2.5 microns and smaller (smoke)
**M$^3$/h:** Cubic metres per hour
**CFM:** Cubic feet per minute
A CIVIC DUTY

COVID-19 Avoid

- Crowding
- Indoors
- Low Ventilation
- Close Proximity
- Long Duration
- Unmasked
- Talking
- Singing
- Yelling
- Breathing hard

https://tinyurl.com/FAQ-aerosols
References

• WHO Roadmap to ventilation during COVID-19
  • https://apps.who.int/iris/bitstream/handle/10665/339857/9789240021280-eng.pdf?sequence=1&isAllowed=y

• Harvard Healthy Buildings
  • Risk calculators, ventilation estimators, portable air cleaner calculations
  • https://forhealth.org/tools/

• SAFEAIRSPACES COVID-19 Aerosol Relative Risk Estimator
  • Risk Calculator: https://safeairspaces.com/safeairspaces-estimator

• Sonora Environmental Research Institute
  • Resources for small businesses on COVID-19
  • https://seriaz.org/business-assistance/supporting-small-businesses-during-covid-19/

• Six Ways to approximate Air Flow (American Industrial Hygiene Association)
QUESTIONS & DISCUSSION

Chris Kopach
ckopach@arizona.edu
(520) 241-6482

Paloma Beamer
pbeamer@arizona.edu
(520) 626-0006
Figure: estimated relative risk of COVID-19 transmission for different activities. 
Table from Jones et al. (2020), as redrawn by the Washington Post. 
(We understand that the table is qualitative, and there is some debate about some details. We plan to work in an improved version of this table using the aerosol transmission estimator).

https://tinyurl.com/FAQ-aerosols